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THE PSYCHOLOGICAL BULLETIN

GENERAL REVIEWS AND SUMMARIES

THE SELF IN RECENT PSYCHOLOGY: A CRITICAL SUMMARY[1]

BY MARY WHITON CALKINS
Wellesley College

I. The word self does not loom large in recent psychological literature[2] but none the less, according to the observation of the writer, psychology, however defined, is more and more often treated neither as the study of mental states, contents, or processes, nor yet as the science of psychic functions, but as the science of selves, or persons. Three causes have of late contributed to this result: the vigorous onslaught of the behaviorists on the exclusively "structural" conception of psychology, the development of social psychology, and the heightened attention, during the time of the war, to problems of personnel, of morale, and of mental reconstruction.

1. It would, of course, be preposterous to claim the out-and-out behaviorist as a self-psychologist; in truth, his rejection of introspection as a psychological method proves that he is really

[1] This is the third in a series of "general reviews" of which the first was printed in the BULLETIN of January, 1912, and the second in the BULLETIN of January, 1916.

[2] The present writer uses the word "self" in sense *a* of the Psychological Association's "Definitions and Delimitations of Psychological Terms" (9. Cf. definition 20, *a*. Cf. also definition 4, comment 2, and definition 23, comment 2 to indicate "a conscious individual [or unique being], characterized by persistence and by change"). She agrees with Laird (16) that the term "self" is best "used by any one who desires an unaccented reading of the problem" (p. 7[2]); yet she is entirely willing to accept as synonym, either "person" or "mind" if the former term is not limited in its application to the complex or the developed self only, and if the word "mind," as synonym for "self," is scrupulously distinguished from "mind," in the sense either of "soul" or of "totality of mental phenomena."

no psychologist at all but a biologist concentrating his attention on human behavior.[1] The strength of his appeal lies in what Kantor (15) calls his "splendid attack upon the mechanics of mental states" (p. 6), his protest against the recognition of that pale abstraction, the mental process or state of consciousness, as the unit of psychology. But, by this attack on the exclusively structural form of psychology, the behaviorist, however unwittingly, is taking the side of the self-psychologist, though the concretely real being by which he seeks to replace the "mental state" is biological, not psychic—the body, not the self. There is, however, no inherent reason why the term behavior should not be used as well to designate the response of self, as to designate the response of body, to environment. Mrs. De Laguna's protest (10) against "Dualism in Animal Psychology," though written in a behaviorist vein and, doubtless, with no self-psychological prepossession, is hardly comprehensible except on the supposition that she conceives her "pleasurably excited dog" and her "angry nurse" each as a conscious self (pp. 619 ff.). And Miss Preble tells us (20) that her attempt to conceive psychology as "science of the conduct of living creatures" always involves, "even in the case of the lower animals," an attempt to answer the "the question, 'How does he feel as a whole?' 'What does he think of his experience?'" (p. 259[1]). Bawden (2) more explicitly states that the behaviorist should take account of the self. So far from rejecting introspection he believes that "all data of science are data of individual inspection in a sense." And he bases his analysis of the concept of behavior on the observation that "we behave not merely as things and as organisms but as persons" (p. 174[4]), regarding "the acts of persons as a distinct type of behavior." This position closely resembles that of Kantor (15) who writes from the point of view of the "functional" psychologist. To Kantor, also, psychology is the science of conscious behavior (p. 7, with note). And though he incidentally refers to the "mental function" (p. 2) and the "psychophysical attitude" (p. 3), he virtually yields to the "conscious being" (p. 3[1]), the individual (pp. 4[3], 10[2]), the central position in psychology.

2. It is scarcely necessary to argue that social psychology, explicitly or implicitly, is conceived as the science of grouped or

[1] Perhaps the most telling recent criticism of this extreme form of behaviorism is contained in an untechnical paper by Fite (14). It is devoutly to be hoped that Fite's undiscriminating and mainly unjustified polemic against experimental psychology may not blind the psychological reader to the pertinence of his protest against biology camouflaged as psychology.

associated selves or persons. Thus Ellwood (12) contrasts social psychology with sociology precisely on the ground that it "aims at explaining the psychological nature of the individual," not that of the group (p. 59[2]); and, in his more recent text (13) says briefly that "the social psychologist studies the psychical interactions of individuals" (p. 9). Bentley's treatment (3) of the problems of social psychology is particularly noteworthy not only because of the genuine contribution which it makes, but because Professor Bentley approaches problems of social psychology with the equipment of an introspective psychologist highly trained in the structuralist's methods. The diverse "tasks of social psychology . . . all rest finally," Bentley points out, "upon social interaction—upon the fact that individuals tend to believe and to think, to feel and to resolve, to speak and to act, to labor and to create, in mutual dependence" (p. 1). "It is possible," he continues, "to look upon the individual . . . as the *unit in social interaction*. When so regarded the individual usually becomes the 'self' and society the congregation or hierarchy of selves" (p. 2[2]). This conception of the socially interacting self in a society of selves in fact underlies Bentley's brief but illuminating treatment of the problems of social psychology. Especially significant from our point of view are (*a*) the distinction (which Bentley finds neccessary to his comparison of the "congregate" with the "assemblage") between the "more passive" and the "more active" relation of myself to other people (p. 8); and (*b*) the doctrine of the "social object" (pp. 13 ff.) whose "meaning . . . implies more than one observer." He stresses two related points, significant in view of frequent criticisms of self-psychology, first, that "the 'implication of observers' is not a logical implication," that rather "the plurality of observers is a part of the object's meaning," and, second, that "the observer, whether myself or another, is not a logical abstraction" but "a part of the concrete meaning which constitutes the object" (p. 14[2]). "As social meanings grow," Bentley continues, "the observers of an object or an event assume more and more the character of partakers." He distinguishes this experience in which "the observers *share* the object" from the "beginnings of social reference" which are, he says, "probably to be found among mammalian forms below man—and possibly among certain of the insects." Here, "the object is already apprehended as the common junction of observations," but "communication is apparently not yet established among the observers for the reason that the *partaking* reference is still wanting" (p. 15[1]).

It is to be regretted that in the fourth section of his paper Professor Bentley, while protesting ably against the tendency of sociologists to conceive suggestion and domination as abstract semi-mythical forces (p. 12[2]), expresses the opinion that, unlike "the sober, and authenticated facts" of physical stimulus and neural disposition, "the mind of my neighbor" is not to be conceived "as a condition of my mental processes" (p. 11). This seems to run counter to the whole trend not only of Bentley's discussion but of the supplementary papers (in *Psychological Monograph* **92**) by Helen Clark on "The Crowd" and by C. H. Woolbert on "The Audience." These papers, all three, throughout treat the psychic individual, the self, as if he were to the full as sober and empirical a fact as any stimulus or disposition though, of course, a fact of another order.

Several writers have discussed the nature of the self's awareness of other selves. Laird (**16**) believes that we have "a direct acquaintance with the experiences of other minds" (p. 24[2]). It is, he admits, "too fragmentary and ambiguous to be the sure foundation of a theory." But he adds that "to deny it *in toto* is equally unjustifiable" (p. 27). He supports this view (against the common belief that we infer the existence of other selves from their bodily gestures) by the observation that men "know their own experiences better than the physical expression of them while they can describe minutely . . . the expressive behavior of others" (p. 27). This is essentially the position of Mrs. De Laguna (**10**), that we directly know, and do not infer, the experience of animal or human companion, that for example "the child . . . perceives his nurse's anger as immediately as he does her position between the chair and the table" (p. 621[2]). In this connection, it is interesting to contrast with Kantor's conception of the "individual" as a psychophysical being (**15**, pp. 3ff.) Laird's distinction of the body as an object "peculiar to a single percipient" from other external objects which are "common to many percipients" (p. 56); and his conviction that the body "is not the self" and is not "part of" self, but rather "belongs to" self (pp. 47, 75, 79). The relation of body to self and the nature of the communication between selves are discussed also, by the writer of this notice, in a paper, mainly philosophical in outlook, on the personalistic conception of nature (**7**, pp. 133ff.).

3. The recent literature of intelligence tests tends more and more to use the language of self-psychology, to describe the testing not

of imagery or memory or psychic function but of a given man's ability to imagine, remember, resolve. "The subject," Terman says, (**21**) "is . . . given tests of memory, of language comprehension . . . , of ability to follow directions. . . . The average of a large number of performances thus gives a kind of composite picture of the subject's general intelligence" (p. 163). In a word, the unit of the intelligence test has come to be the conscious self. And even more unambiguously psychology confronting problems of personal efficiency deals with the self, not with the "content" or the "function." The very title of Lough's useful little volume (**17**) confirms this statement; and Dodge explicitly makes "the difference between a person and a thing" (p. 137) the basis of his outline study (**11**) of the "conditions of effective human action."

II. In turning from the incidental to the specific discussion of the self, we shall find it convenient to make our start from the vantage ground of the critics. The most important attack on the conception of psychology as science of self is that of MacDougall (**18**). His position, resembling that of Natorp, Dürr, and Dunlap[1] is the following: Far from denying the existence of selves, he asserts that "every mental fact is the experience of some self" (p. 9[1]), again that "of facts not given to a subject we know nothing" (p. 8[3]), and that "the sense of self accompanies and grounds all experience" (p. 9[2]); finally, and even more impressively, that "all psychology is the psychology of self" (p. 29[2]). None the less, he insists that the conception of self has "merely regulative value" in psychology (p. 11[2]). And he bases this conclusion, which in face of the admissions just quoted is little less than astounding, on two main considerations, closely related: (1) "Self-consciousness," he urges, is not "a fact among facts"; it is not "a constituent of experience as is sensation . . . or affection" (p. 9[3]). (2) The self, in the second place, is not a proper object for scientific description: it "nowhere becomes the object of descriptive treatment" (p. 29[2]). And "the barren reassertion in connection with each fact discussed that it is the experience of a self adds nothing to its treatment" (p. 10[2]).

The first of these criticisms is again brought forward by Creighton (**8**) who argues against the view that "the 'self' is actually a 'perceived' fact, a particular datum of introspection" (p. 166[3]) by pointing out that "the self is no 'psychological state,' no 'specific self-content'" (p. 167[2]). In the opinion of the present writer

[1] Summarized in this BULLETIN of January, 1916, pp. 13, 22–23.

both Creighton and MacDougall unjustifiably identify the obvious truth that the self is unlike all other observed facts with the assertion that the self is not an object of observation. Assuredly the self is not a "fact among facts" of psychology, for it is basal to these other facts; it is not a "content" or a "psychological state," for the contents and the states are its own. On the other hand, as both MacDougall (already quoted) and Creighton (for example, p. 168[3]) admit, one does directly know oneself as subject of perceiving, thinking, feeling and willing; and this is sufficient to constitute the self the fact or object of the psychologist's study. Among recent writers, Laird (p. 24[2]) affirms this direct introspective awareness of self; and Parker (**19**) insists (chapter 2) on the "fact" or "experience of personal identity" which he carefully distinguishes from the "concept" of personal identity.

The second of MacDougall's criticisms finds a certain justification in the lazy contentment of many self-psychologists with traditional structural categories or with unassimilated, behavioristic descriptions, supplemented by the truly "barren assertion" that psychic facts belong to the self. Angell for example, in the last chapter of his *Introduction to Psychology* (**1**) seems to regard the book as an analysis of the "experiences" of the "personal self" (p. 263) but nowhere analyzes and describes and groups these experiences as essentially related to the self, as intrinsically personal experiences. Yet, it has over and over again been shown not only that all psychic phenomena may be described as experiences of a self but that many of them are inadequately and equivocally described without this reference to conscious self or selves. Thus, sympathy and jealousy are indistinguishable from other forms of feeling except when described as consciousness of oneself in relation to other selves; the awareness of the persisting self is the core of recognition (cf. Kantor, **15**, pp. 10 ff.); and realized self-activity is the essence of volition.[1] The greatest need of psychology to-day, in the opinion of the writer, is the thorough, experimentally guided working out by many minds of the specific categories of self-psychology. Without this systematic and scientific detail-study of self-psychology we seem doomed to vibrate between the abstractions of structural psychology and the rule-of-thumb procedure, or else the wild eclecticism of most mental testers and applied psychologists.

[1] Cf. Pfänder, *Einführung in die Psychologie*, summarized in this BULLETIN, January, 1916, 13, 25; and the writer's *Introduction to Psychology* (1901), Chapters XIV–XXI, and *A First Book in Psychology*, Chapters II, VIII–XIII.

Indications of such analytic study are not entirely lacking. In particular, Laird, in his *Problems of the Self* already referred to—a book written with primarily philosophical purpose but based upon genuinely psychological analysis—resembles Michotte[1] in his distinction of the "adynamic" cognitive attitude of the self alike from the "passive" emotional and the "active" willing attitude (pp. 35 ff.). Important also are the chapters (IV–VIII) in which Laird protests against the conception of the self as exclusively emotional or affective. At most he yields that "feelings are the most intimately personal of our experiences" (p. 87[2]). But he points to esthetic feeling as witness that "feeling . . . is not intrinsically more obviously 'ours' than other experiences" (p. 91[2]). And "how," he persists, "can we say that feeling knows and feeling wills, . . . how can we avoid saying that the self knows and the self wills?"

The criticism of self-psychology contained in Titchener's latest volume (**22**) runs along the accustomed grooves. Self according to Titchener reduces either to the mythical "soul" of the animists, the "mannikin-mind which was assigned variously to heart, liver, eye, brain, blood" (p. 10) or else it is a common-sense, ethical affair, which cannot lend itself to scientific treatment. Against the first of these conceptions, the identification of the "self" of the psychologist with the "soul" of the metaphysician, the writer of this review has protested in several papers (**4, 5, 6**), all aiming to free the self from entangling alliance with the soul, whether this be conceived as *Körperseele* or as empty substance or as "entelechy" intruding unaccountably in the series of vital phenomena. (Such a protest might, by the way, with great advantage, be directed against the extraordinary *volte face* of Laird's last chapters, which virtually identify "self" with "substance.") In comment, finally, upon Titchener's steadfast refusal to admit the possibility of a scientific study of the self the following statements may be made: Titchener is of course abundantly justified in the conviction that the self is often treated in moralizing, unscientific, "every-day" fashion. But this does not preclude the possibility, and indeed the psychological necessity, of dealing with the self scientifically, as well. Observation of the straits to which Titchener is driven in his attempt, without recourse to the self, to distinguish psychology from physical science constitutes a sort of negative argument for self psychology. "Psychology," according to Titchener, is "the

[1] *Arch. de Psychol.*, 1911, **10**, 195[2].

result" of the "endeavour . . . to describe *the world as it is in man's experience*, as it appears with man left in" (p. 9[1]); and it is contrasted with physical science which sets out "to describe the world as it would be with man left out" (p. 8[3]). When, however, challenged by his own definition, Titchener undertakes to tell us what he means by "man," he has only this to say, that "the *man left in* . . . reduces to a nervous system" (p. 10). But it is perfectly evident that a nervous system is one of the objects of the world of physical science and thus incapable of serving as distinguishing mark of the psychological from the physical. On the other hand one has only to interpret "man" as "self" and Titchener's definition of psychology becomes luminously clear.

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VISION—GENERAL PHENOMENA

BY LEONARD THOMPSON TROLAND

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The year 1918 witnessed the death of Ewald Hering, the veteran psychophysiologist, at the advanced age of eighty-four years. The importance of Hering's contributions to the science of vision are too well known to the readers of this review to require any new emphasis. It is a striking fact that while Hering claimed primarily to be a physiologist rather than a psychologist the lasting part of his contribution to visual problems will probably be found on the psychological rather than on the physiological side, since modern physiological studies do not tend to corroborate his doctrines concerning the metabolism of response. We cannot overestimate, however, the importance of the emphasis which Hering permanently placed on the purely psychological aspects of light and color. Garten (**20**) commemorates Hering's work in an article which outlines his biography and his essential contributions to science and other fields of human endeavor. It is a great misfortune that Hering was not able to complete his *Grundzüge der Lehre vom Lichtsinn.* Carl Hering (**26**) also comments briefly on Ewald Hering's contributions to physiological optics.

The two related problems of the visibility of radiation and the merits of different methods of heterochromatic photometry continue to occupy the attention of a considerable number of investigators, mostly American. The important papers of Coblentz and Emerson (**8, 9**) were reviewed last year on the basis of advance publications. These studies on visibility were made by the flicker method. Further measurements by this same method are reported by Reeves (**63, 64, 65**), in which thirteen observers were used, the wave-lengths ranging between 490 and 640 $\mu\mu$. The maximum of the average curve was found to be at 553 $\mu\mu$, which is closer to that

found by Ives than that by Nutting, and the total curve is slightly less broad than that found by either of the last mentioned investigators. The energy calculations were based upon improved data.

Hartman (**22, 23, 24**) reports some very careful work on the visibility of radiation in the blue end of the spectrum, which is needed to strengthen existing measurements for these wave-lengths. Instead of flicker a direct comparison method was employed which utilized a photometric field similar to that of the Holborn-Kurlbaum optical pyrometer. The range of wave-lengths covered was from 410 to 500 $\mu\mu$, and the energy values were calculated from the known radiation laws of the tungsten filament. Twenty observers took part. The results agree fairly well with the visibility curve of Nutting but are considerably lower than those obtained by Coblentz and Emerson. For the extreme blue-violet they are lower than those found in either of the last named investigations. Relative visibilities at 410 and 500 $\mu\mu$ are 1.7 and 905, respectively.

Hyde, Cady and Forsythe (**32, 33**) have thought it worth while to supplement this work by determining the visibility curve anew between 500 and 660 $\mu\mu$ by a direct comparison method, since they feel that the flicker method assigns too great a weight to the red end of the spectrum to be accepted without further criticism as the standard method of heterochromatic photometry. Results obtained by the flicker method may differ by 2.5 per cent. from those obtained by direct comparison, and the general form of the visibility curve seems to be different for the two methods. The present measurements were made under conditions identical with those of ordinary photometry, and a constant brightness of 0.003 candles per square centimeter, with an artificial pupil, was maintained. The comparison between wave-lengths was established by the "cascade" method, the spectrum being stepped off 10 μ at a time so that a barely noticeable color difference existed in any given comparison. Energy estimates were based on the laws of radiation for tungsten. Twenty-nine observers took part and their average visibility curve was found to be narrower and relatively lower in the red end of the spectrum than that obtained by the flicker method. Since the agreement between different observers was satisfactory the new curve is recommended as a standard in place of that obtained by flicker. Supplementary investigations were made using Hartman's "pyrometer method" in the middle of the spectrum, and the curve was found to be somewhat flatter than that obtained by the cascade procedure, although it agreed with

the latter better than with the flicker curve. Finally a table of weighted visibility values for the entire spectrum based upon direct comparison is presented.

Ferree and Rand (18) (1917) have made careful measurements of visibility curves at a number of different intensity levels and find that the form of the curve varies radically with intensity, even for intensity levels similar to those utilized in previous elaborate investigations by others. The change in the form of the curve is of the sort well recognized as constituting the Purkinje phenomenon. The changes in visibility for certain wave-lengths due to intensity amount to many hundred per cent. Unfortunately the writers do not specify the size of the field employed, so that one cannot feel certain that strictly foveal stimulation was secured. Energy values were obtained by direct radiometry in accordance with methods already exhaustively presented by the authors.

Priest (56) discusses a further development of the fact previously pointed out by the writer of the present review that if the empirical visibility curve is corrected for the selective absorption of the ocular media the resulting retinal visibility curve is almost perfectly symmetrical. It appears that this symmetry is more perfect when the corrected values are plotted with respect to frequency—which is theoretically the most promising method—than with respect to wave-length. Coblentz and Emerson's visibility data when thus corrected and plotted are symmetrical about a maximum at 541 vibrations per trillionth of a second. The symmetry is startlingly precise between frequencies corresponding to wave-lengths of 490 and 690 $\mu\mu$, that is, in a region where we are reasonably sure that no adventitious influences, such as retinal fluorescence, etc., are at work. The curve is accurately representable by a simple probability equation.

A number of studies relate to the principles and practical methods of heterochromatic photometry. Stenholm (67) describes what purports to be a new method in this field. The method of comparison, however, does not appear to differ in principle from that of the familiar Rumford shadow photometer, although he claims for it a considerable precision when applied to lights of different colors. Ives (37) presents a revised formula for his so-called "luminosity curve solution" for "physical photometry." This solution has a spectral transmission corresponding with the latest visibility curve results. Revised formulæ are also offered for solutions of two different colors which should appear to have equal light transmissions for the normal eye and a "4-watt lamp."

Crittenden and Richtmyer (13) describe statistical investigations with 115 observers in which the above mentioned Ives-Kingsbury test solutions were employed in order to establish a reliable criterion for the "normal eye" as regards visibility. They find that for accurate heterochromatic measurements a careful choice of observers is essential, although by the use of the test solutions it is possible not only to choose normal observers but to correct the results obtained by an observer deviating from the normal. In the same paper an investigation is reported of the difference between results obtained by the flicker and the direct comparison methods of photometry for compared lights differing in color to the extent exhibited by the range of common illuminants. They find that the two methods may differ as much as 3 per cent. for these relatively small color differences. The work reported in this paper was done a number of years ago.

Troland (69, 70) reports measurements of the differential threshold for brightness between all possible paired combinations of eight spectral colors. The colors selected were the so-called psychological primaries and their intermediaries. The results show that the threshold increases to a maximum of from five to ten times that for zero color difference when the color difference is a maximum. The law connecting this relative increase with hue scale difference is the equation of an ellipse. Theoretical studies are presented of the magnitude of the heterochromatic threshold between various characteristic pairs of colors, such as antagonistic and non-antagonistic primaries, etc. It is found that on the average the threshold is greater for antagonistic pairs than for non-antagonistic ones and greater for pairs of warm with cold colors than for warm with warm or cold with cold. A general psychological theory is outlined to explain the influence of color difference upon luminosity discrimination and the relation of this theory with the color pyramid is discussed.

Hols and de Visser (28) report a new determination of the brightness of the black body at 1,336 degrees finding it to be 0.119 hefner candles per square centimeter. This determination permits them to calculate the mechanical equivalent of light to be 51.7 hefner candles per watt.

A number of papers deal with the practical application of the principles of vision.

Ferree and Rand (16, 17) report further experimental investigations on the power of the eye to sustain clear seeing under different

conditions of illumination. The problem which they attack in the present papers is the much debated one of the relative merits of different common illuminants. By means of their familiar test the authors demonstrate a considerable difference between the various types of tungsten lamps, the carbon lamp and the kerosene flame. The ordinary "nitrogen" lamp appears to be most conducive to efficient seeing, while the semi-daylight lamp is least conducive, the kerosene flame lying somewhere between these. The results are given in detail.

Luckiesh contributes two papers in the applied field. The first (45) deals with the artistic possibilities of artificially colored illuminants. He discusses the problem of the emotional correlations of the various colors, the recent advances which have been made in the standardization of color and the technique of producing various colors. In the other paper (43) Luckiesh touches on some of the visual principles involved in camouflage. Mention may be made here of the same writer's very interesting volume "on the language of color," which considers in a semi-fanciful vein the rôle which color has played in literature.

Miss Irwin (34) also discusses the value of color in illumination. She classifies colors according to their emotional effect and applies the principles thus developed to the practical purposes of "utility, beauty and hygiene."

Troland (71) presents certain psychological considerations bearing on the applications of color to problems of illuminating engineering, pointing out some undesirable confusions which exist in the present usage of the term "color" and the importance of regarding color at all times as a psychological factor. The problem of the subjective reproduction of "daylight" vision by artificial illuminants is discussed from a psycho-physiological point of view and the thesis is advanced that both adaptation and association act in consciousness in such a way as to add blue to all of the perceptions of evening vision. The problem of the definition of "white light" is considered in conjunction with that of the color of sunlight. Among other theoretical points discussed are those of the nature of the physiological process in the visual nervous system, the definition of primary colors, the significance of Hering's psychological color system, and the evolutionary basis of color vision.

Troland also reviews the important experimental work of Pressey on the influence of color upon mental and motor efficiency. Even the very elaborate experiments made by this investigator, who used

a variety of "mental tests" upon subjects subjected to illumination of various colors, failed to demonstrate any appreciable effect of color upon mental performance. Brightness, however, was found somewhat to enhance the efficiency of performance.

The committee on automobile headlight lamps of the Illuminating Engineering Society considers in some detail (**10**) the application to their particular problem of the laws of visual sensibility developed by Nutting and others. New data on reduction of sensibility by oblique glare at various angles and on other relationships relevant to the headlight problem are presented. The threshold sensibility is found to increase with the size of the stimulus spot for low but not for middle or high intensities. Contrast sensibility, as shown by the measurements of Reeves, also increases rapidly with increase in the size of the test field. The effects of rates of adaptation, temporary glare, and "veiling glare" are also considered, and the brightness distribution needed for the best seeing is specified. Similar problems are discussed by Bayliss (**3**) in a paper presented to the British illuminating engineers. A contrast of 100 to 1 is suggested as the maximum desirable in any field of view. The effect of color on clearness of seeing, and conditions of eye-strain are also considered in relation to the theory of vision.

The work of Reeves adverted to above is presented by that investigator himself in a number of quantitative articles dealing with the effect of stimulus size on the absolute and differential brightness thresholds. One of the investigations (**59, 60**) (1917, 1918) provides us with measures of the differential threshold for angular sizes of the test field ranging between 0.33 and 4.92 degrees and times of adaptation between zero and 60 seconds. For angles greater than one degree, the logarithm of the absolute brightness required to render a given contrast visible is reciprocally proportional to the visual angle, but the variation is much less than for smaller angles. The time required to detect a fixed contrast with various field sizes and brightnesses is also determined. Comprehensive tables and graphs are included, and these must be studied to obtain a thorough appreciation of the results.

The other investigation (**58**) is concerned with the energy and brightness required for absolute threshold stimulation with stimulus fields of various angular sizes and shapes. The conditions were those of fairly complete dark adaptation. The threshold in terms of total energy entering the eye increases from 17.1×10^{-10} to 564×10^{-10} ergs per second in passing from a square field one milli-

meter on the side, viewed at a distance of three meters to one twelve centimeters on the side, viewed at a distance of thirty-five centimeters. His measurements were made in brightness units and transformed into energy units by means of the mechanical equivalent of light. The threshold brightness for the smallest field was .00720 millilamberts and for the largest .000000175 millilamberts. The average time required to perceive a just noticeable stimulus was found to be 2.2 seconds.

Another elaborate series of investigations from the Eastman laboratory is reported by Blanchard (6). Some of this worker's investigations on visual sensibilities of various types have already been published by Nutting. He finds that the instantaneous absolute brightness threshold after adaptation of the eye to different levels of brightness is an exponential function of the latter brightness, the form of the equation being $T/F = (F/F_0)^{-n}$, in which T is the threshold, F the field brightness, F_0 the absolute threshold, and n a constant. Upper and lower deviations from this law analogous to those exhibited by Fechner's law are demonstrable. A change in the value of n for light of different colors is found, which appears to depend upon the same mechanism which underlies the Purkinje phenomenon, the test spot in these experiments having an angular size of approximately 5 degrees. Measurements are also reported on the differential threshold or contrast sensibility immediately following adaptation to various brightness levels. A number of different physically fixed contrasts were employed, and the brightness behind these was varied until the contrast could just be noticed after each specific adaptation. The time allowed for detection of a given contrast was also controlled. Curves are given showing the relation between the adaptation field brightness and the relative differential threshold for various times allowed for discrimination to occur. The threshold rapidly sinks to an asymptote with increased field brightness. A third question considered is the value of the unit of brightness employed by König in his classical investigations on the differential threshold for brightness. By a comparison of the form of the curves obtained by König with those obtained by himself Blanchard concludes that the unit in question was .0040 millilamberts. A fourth problem is that of the brightness which is just glaring after adaptation to a variable level of brightness. The equation expressing this relationship has the form $G = cB^n$, where G is the glaring brightness, B the adaptation brightness, and c and n are constants. The range within which

sensibility to glare changes with adaptation is much less than that characterizing the absolute threshold or contrast sensibilities.

Another series of measurements was concerned with the rate of adaptation, the absolute threshold being determined as a function of the time after adaptation of the eye to fields of varying brightness and color. Curves are presented showing the relationships between the various factors in this situation. The color of the field appears to have an effect in harmony with that predictable on the basis of the Purkinje phenomena.

Still another problem treated in this extremely comprehensive paper is that of the diameter of the pupil for different field brightnesses both for monocular and binocular exposures. Curves are given showing the relationship between brightness and pupillary diameter for each of these conditions, the ratio of maximal to minimal diameter being 16. On the basis of these results the flux density of light on the retina is calculated for various stimulus field brightnesses varying from $7. \times 10^{-12}$ lumens per square meter for the threshold brightness to 1.1×10^{-4} for a brightness of 2,000 millilamberts. As is evident from the above incomplete summary, this paper represents a very large amount of quantitative work of the highest type, although it was apparently carried out with only a few subjects.

Best (5) (1917) has carried out measurements of the adaptation process for both central and peripheral vision, using "radiolite" screens of various brightnesses as test objects. The sensitivity in the periphery doubles in a few seconds at the beginning of dark adaptation and after forty-five minutes has increased by a factor of twelve. Central adaptation is soon finished, although adaptation to red continues after that to violet is complete. The relative apparent brightnesses of lights of different colors in the dark-adapted central and peripheral fields are discussed, and the facts appear to be consistent with the recognized theory of relative rod and cone sensitivities, for various parts of the spectrum. Other papers touching on the "duplicity theory" are those of Rochon-Duvigneaud (66) (1917), Polack (54) and Koeppe (41). The first bases arguments with regard to the functions of the rods and cones on a demonstration that nocturnal saurians are equipped only with rods, whereas diurnal ones have cones alone. Polack finds that in congenital day-blindness a reverse Purkinje phenomenon exists, no exception to this rule being noted in five cases which were studied. There is no photochromatic interval in such cases, except for green

light. Koeppe attributes night blindness to opacity of the lens rather than to disease of the rods.

Lumière (47) reports as a new observation what is in reality only another instance of the principle of which the familiar "fluttering heart" illusion is an example. If a luminous watch dial is moved back and forth in the red light of a photographic dark-room, the figures appear to oscillate upon the dial. Other experiments illustrating the same fundamentals are described and deductions are drawn regarding the rates of rise and decay of different color excitations in the retina.

Some very interesting observations of a similar effect are described by Ives (36). He finds that if a compound strip of light, the upper portion of which is red, the middle purple, and the lower blue, is moved through the visual field at the right speed the blue not only lags behind the red but the purple breaks up into red and blue components. A similar effect is found with a yellow composed of red and green lights, although it is quite absent with a monochromatic yellow. The general law governing these phenomena therefore seems very similar to that of optical dispersion, although the true explanation is probably that the excitations set up by the different wave-lengths in the retina are propagated to the brain at different rates, a view already clearly expressed in the author's theory of "visual diffusivity." The phenomena, however, are observable only at low intensities, and their *chromatic* character does not appear to be very convincing, both of which considerations cause one to wonder if they may not, after all, be referable to the well-known lag of rod excitation behind that of the retinal cones. It is to be regretted, at any rate, that neither Ives nor Lumière make any reference to the literature which deals with the Purkinje after-image or with Fechner's colors. Baumann (2) finds that the latter phenomenon is not observable in bright sunlight, and is interfered with by flicker.

Perhaps the most impressive monograph of the year is that of Hartridge (25), who has attacked anew the problem of the chromatic aberration and resolving power of the eye, with super-Helmholtzian acumen. He first examines critically the various hypotheses which have been offered to explain the substantial absence of effects of ocular chromatic aberration in ordinary vision. Helmholtz's well-known explanation appears to be the best, but requires correction as regards the assumed dispersion by the ocular media and the particular wave-length which the eye selects to focus sharply

upon the retina. Hartridge finds this latter to be 580 $\mu\mu$ (the yellow) instead of 500 $\mu\mu$ (the green), assumed by Helmholtz. This experimentally established result harmonizes with the fact that the focusing of yellow provides a maximal concentration of all of the light emitted by a single point of the object. The distributions of light intensity at the borders of retinal images of various shapes and sizes are calculated, and it is shown that in the case of a point source and a 0.9 mm. pupil 76 per cent. of all of the light can fall on a single retinal cone, while the outlying cones receive only 3 per cent. apiece.

The color-mixture effects which are present in the chromatic aberration disks of retinal images are analyzed theoretically, and the conclusions reached are tested experimentally. The eye apparently differentiates between white and yellow points of light by means of the blue ring which surrounds the former but not the latter—since the nuclei of both must be yellow—but this ring is not experienced directly. Eleven factors which tend to reduce the effects of chromatic aberration in the eye are discussed in detail, and the modifications of the aberration in night vision are considered. Chromatic difference in magnification, chromatic stereoscopy, and "chromatic focal instability" resulting from chromatic aberration in the vision of colored objects are other topics which are very carefully analyzed. The optimum resolving power of the eye is about 0.0031 mm., obtained with a pupil not less than 2.8 mm. diameter. Hartridge has apparently not seen the important papers of Nutting on his chosen subject. It is to be hoped, however, that he will extend his very valuable original investigations to other optical problems of the eye, the solution of which is a prerequisite of an accurate analysis of many general visual problems.

Another excellent experimental study of ocular processes is that reported by Reeves in a number of papers (**61**, **62**), on the rate of pupillary dilation and contraction. The range of intensities lying between complete darkness and the brightness of white paper illuminated by direct sunlight was divided into eight levels to be studied separately. Eight subjects took part. The rate of contraction was recorded by motion pictures, and the rate of dilation by single flash-light pictures taken at different times after removal of the stimulus in as many separate tests. The average pupil closes in less than five seconds, but requires three to ten minutes to open to its maximal diameter. Curves showing the rate of closing, after adaptation to darkness, for various levels of bright-

ness, and of opening in darkness after adaptation to these several levels, are given. There are also valuable tables of pupillary diameters for a wide range of fixed brightnesses. Both binocular and monocular stimulation were tried. Other articles dealing with the pupil are those of Barrie (1) who discusses pupillary inequality and finds that it frequently occurs in association with myopia, and Cutting (14) (1917) who describes, somewhat naïvely, experiments showing that the response of the pupil to colored lights is proportional to their luminous intensity, and independent of hue or wave-length as such.

Thomsen (68), after biographical commentary on the work of Purkinje, presents new experimental and theoretical analyses of certain of the entoptic phenomena first described by that classical investigator. The entoptic figures which are produced by intermittent illumination of the closed eyes are divided into the primary and the secondary, the former being referred to the displacement of pigment in the pigmentary epithelium and the latter to the motion of the blood in the retinal vessels. The patterns which are visible are catalogued and described. Figures produced by pressure and by the electric current are also described. An increasing current along the optic axis yields a violet, while a decreasing one gives yellow. The idio-retinal streamings and flashes of light which can often be seen on a strongly illuminated white surface are discussed. A whole section is devoted to the *Aderfigure.* The visibility of the blood corpuscles is attributed to mechanical stimulation, and their increased visibility with blue light as compared with red is explained by a supposed sensitizing action of the former!

Klein (40) reports a case of migraine in which during the onset of the disease a hexagonal network was visible over the entire visual field. He attributes this appearance to chemical substances emitted by the pigmentary epithelium and acting upon the retina. Carter (7) (1917) describes a circular color spectrum which he began in his eighty-ninth year to see surrounding any bright light. The circle is a large one and is quite clear of the light itself. He considers it to be due to some change in the refractive elements of the lens.

Macht, Isaacs and Greenberg (49) (1917) find that opiates, such as morphine and pantopon, have a slight contracting effect upon the visual field, while antipyretics, such as acetanilid and aspirin, show some tendency to expand the field.

William (73) describes preliminary observations on a supposedly unusual case of partial color-blindness. The customary tests with yarns, Nagel cards, etc., indicate the subject, a male, to belong to the familiar deuteranopic class. Perimetric measurements show his color fields to be contracted to a marked degree. His photopic and scotopic luminosity curves for a standard light source were determined in comparison with those of normal observers, both the direct comparison and flicker methods of equation being employed. By the direct comparison method he shows a marked depression of sensibility in the neighborhood of 560 $\mu\mu$, which is approximately the location of his "neutral band," but this effect is absent in the curves obtained by flicker. His response at the red end of the spectrum and his scotopic curves are similar to those of the normal observer, his spectral limits being approximately 400 to 750 $\mu\mu$. Careful hue discrimination tests were made throughout the spectrum, which showed an exceedingly small number of "hue steps," these lying for the most part between 530 to 580 $\mu\mu$. Color equations between mixtures of two homogeneous spectral lights and a single spectral light were made. His neutral band lies at 576.5.

Ishilhara (35) describes a modification of Stilling's test for color-blindness, which consists of sixteen plates with intersecting circles so arranged as to give one salient pattern for the normal eye but quite a different pattern for the color-blind eye.

Houstoun (30) has attempted a "statistical study" of color vision, the purpose of which was to determine whether or not a biometric frequency curve for some property of color vision has more than one mode. The property selected was, unfortunately, the response of the subjects, of whom there were 41, to the so-called Edridge-Greene test for color normality, which consists in determining the number of "monochromatic" regions which the subject can discern in the spectrum. However, the results are undoubtedly of some significance and indicate so far as they go that there is only one *type* of color vision, the "scatter" of the normal frequency curve being sufficient to include the color-blind cases. This is a very laudable type of work, but it is to be wondered whether the conclusion reached would be corroborated by analogous determinations using a more reliable criterion.

Houstoun appears to take Edridge-Greene's test rather seriously, since he devotes another article (31) (1917) to the problem as to whether Sir Isaac Newton was a "heptachromic" in Edridge-

Greene's sense, as Newton regarded the "indigo" region of the spectrum as a characteristic one, while the majority of observers do not so regard it.

Malling (50) has studied twenty-five cases of abnormal color vision using five color equations between different parts of the spectrum, determining the length of the spectrum and the location of the neutral band whenever the latter was present. His results, like those of Houstoun, indicate a continuous series of variations from the normal to the color-blind individual. The neutral zones vary in position but are usually between 500 to 550 $\mu\mu$. Only an abstract of this work is available, but it appears to be of considerable value.

A number of articles deal with the theory of visual sensation. Houstoun's theory, already reviewed, has been republished (39) and is worthy of careful consideration. Bayliss (3) contributes an interesting paper on the physiology of the retina, although it is largely a summary of well-known facts. The minimum retinal energy threshold is asserted to correspond to one "light quantum" of the Plank theory of radiation. Temporal laws of retinal excitation are considered by means of electrical response curves for a number of different organisms.

Berry (4) (1917) in a Bowman lecture has analyzed the problem of color vision very carefully, and arrives at the following conclusions, among others. It is improbable that there are any fundamental color sensations, so that the transition from trichromatic to dichromatic vision is not to be explained by the loss of one fundamental sensation. Special cortical processes which are independent in their nature of the retinal ones must be assumed. Chromatic and achromatic sensations have separable mechanisms, the rods and visual purple having no connection with color sensation.

Gibson (21) offers a popular but accurate account of the nature of light on the modern electron theory and points out the probable relation between this theory and the facts of color vision. He believes that there are three types of resonating electron systems in each retinal cone corresponding with the three fundamental sensations of the Young-Helmholtz theory, and that dichromatic color-blindness is due to the absence of the red-sensitive system. This latter belief is substantiated by demonstrations showing that normal observers make the same errors in color choice when working in a "minus red" illumination that the color-blind make in ordinary illumination. The red and green responses are supposed to combine to produce a new form of "chemical disturbance," as are also

the red, green and blue, thus accounting for yellow and white respectively. The transmission of color quality to the brain is supposed to be accomplished by means of some characteristic "interruption of the local nerve current."

Dawson (15) (1917) supplements his paper previously reviewed with one on the theoretical side of the question of binocular color mixture. The present paper is a very careful historical, as well as logical, analysis of the problem and contains much food for thought. The facts indicate that binocular color mixture is possible and that like other phases of binocular fusion it is difficult to explain as a result of the combination of the two ocular impulses in a single cortical field. Binocular rivalry, the opposite of binocular fusion, appears to be most satisfactorily explicable as a phenomenon of attention, since its governing conditions seem to be the same. This view is substantiated by a careful analysis of the conditions in question, such factors as contour, local fatigue, volition, involuntary fluctuation, and interest being considered. The theoretical implications of the phenomena of luster, transparence, and Fechner's paradox are considered.

Zeeman (74) (1917) asserts that there is no trace of binocular summation of brightness either for a light or dark adaptation of the eye, although the threshold is lower for binocular than for monocular vision. This is to be attributed to an increased sharpness of perception of the outlines of the object in binocular vision.

Pikler (53) has devoted a number of chapters in his recent book to problems of binocular vision. He regards sensation as conditioned by a process of adaptation (Anpassung), a view somewhat resembling that of Hering. The single effect of vision with two eyes is explained according to the view that a single process is released by either eye, no further release being accomplished by the two eyes acting in unison.

Luckiesh (46) describes some very interesting experiments on phenomena of chromatic stereoscopy. Red and blue letters were observed in a dark room and the observer was required to move the former until the two appear to be the same distance from the eye. For seven observers the red had to be placed considerably farther away than the blue, although the opposite was the case with two other observers. The effect of different distance value is absent when small artificial pupils are employed concentrically to the optic axes or when only one eye is used. However, it is present when the pupils are placed eccentrically, and can be reversed by

reversing the eccentricity. On the basis of these observations a theory is advanced which explains the effect by a combination of the chromatic aberration of the eye with the disparation principle of ordinary stereoscopic vision. The author is apparently unfamiliar with the literature on this subject, in which similar explanations are already to be found. This literature is reviewed critically by Hartridge (**25**).

There are a number of valuable contributions dealing with methods and apparatus. The Annual Report of the Committee on Nomenclature and Standards of the Illuminating Engineering Society should be in the hands of all workers on vision. Besides summarizing the established conceptions related to light and radiation, this report offers revised definitions of brightness and the lambert, the unit of brightness. A standard table of visibility values in steps of 10 $\mu\mu$ between 400 and 760 $\mu\mu$ is given, both relative and absolute (lumens per watt) values being tabulated.

Priest (**57**) gives an outline of the work being undertaken by the National Bureau of Standards on the establishment of color standards and methods of color specification. This work includes "development of instruments and methods for general fundamental work, determination of fundamental data and establishment of working standards, application of spectral photometric and colorimetric methods to specific technical purposes and routine tests." "The fundamental basis of color specification is spectrophotometry." Coöperation and discussion with outside experts is sincerely desired. Reference is made in this paper to a method more thoroughly described in a further publication (**55**) by the same author for a production of accurate "artificial daylight." This method utilizes the rotary dispersion of a quartz plate inserted between two crossed Nicol prisms. Reproduction of the distribution curve of solar radiation between 520 and 690 $\mu\mu$ can be secured by means of this principle with an accuracy of 2 per cent. or better.

MacDougal and Spoehr (**48**) (1917) enumerate the various physiological effects of light, discuss the relative merits of gelatine and liquid filters, the properties of various selectively transmitting glasses, and recommend the use of a photo-electric cell for measuring radiation intensities.

Laurens and Hooker (**42**) (1917) describe an apparatus for producing spectral lights and equating them in energy. This equation is accomplished by means of a thermopile and galvanometer and the conditions necessary to accomplish the result are

carefully tabulated. The writers are at present working on the relative stimulating values of these equated lights for various organisms, as well as their values in chlorophyll metabolism.

Karrer (38, 39) describes a new neutral tint or variable tint screen, which consists of a number of small glass bars with a very thin layer of black opaque or colored material between them. Alteration in the angle between the screen and the incident beam of light permits continuous variation in the intensity amount of the latter which is transmitted. The screen has a very high maximal transmission.

Gaehr (19) describes class-room methods of demonstrating the Purkinje phenomenon and the persistence of vision.

Some interesting studies in the comparative field are reported. Hess (27) gives an account of experiments which prove that bees have no color vision, since they are unable to distinguish yellow and blue from each other or from a gray when these are of equal luminosity for the color-blind human eye. The temporal laws and circumstances of adaptation in the bee appear to be similar to those for man, but there is no Purkinje phenomenon in the former instance. Hess shows that the experiments of Von Frisch, which the latter experimenter regarded as demonstrating color vision in the bee, in reality prove the absence of such color vision.

Wasmann (72) reports experiments which show that the ordiary house-fly (*Homalomyia cunicularis L.*) is insensible to the light transmitted by a ruby glass.

Mottram and Edridge-Greene (51, 52) discuss "animal coloration from the point of view of color vision." They believe that "sexual differences in color in birds and insects can be entirely accounted for on the basis of a difference in conspicuousness." In general, red tends to produce conspicuousness at low illuminations while blue has the same result at high illuminations. The enemies of insects cannot discriminate between a green and a brown, and since a brown pigment is most readily produced by these animals they employ it to render themselves invisible against a foliage background. A detailed examination of many specific cases is given.

The Committee on Progress of the Illuminating Engineering Society (12) reviews and abstracts the work on the physiology of vision during 1917–18, so far as it bears upon their field.

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VISION—COLOR DEFECTS

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Among the limited number of articles which have appeared since the last review of color defects in 1916, the following wide range of topics is discussed,—color tests, the frequency of color-blindness, the relation of color defect to visual acuity, unusual cases, the classification of color defects, and color therapy.

Collins (3) presents the results of the examination of 1,000 persons with the Edridge-Green color lantern, a task undertaken as a part of an illumination survey of the Federal department buildings in Washington, "with a view to determining both the value of the lantern in testing color-blindness, and the effect, if any, of refractive conditions, lesions, and anomalies of the eye, and also the effect of sex upon different degrees of color perception." Collins gives a sympathetic presentation of the Edridge-Green theory as a preliminary to the explanation of the construction and use of the color lantern. The Holmgren wool test is also explained and criticized and a special study of Jennings's recently devised self-recording worsted test described. Four tables are printed showing the frequency of ocular defects in the 1,000 persons examined, and the relations of ocular defects to color defects. The author summarizes his results as follows: Color blindness is best detected by testing with colored

lights of known spectral composition. It is of great importance to divide the color blind into the dangerously color blind and the harmlessly color blind. Among the former the author would include: (*a*) Those possessing a color perception containing three or less units; (*b*) those possessing a greater number of units than three who have the red end of the spectrum so shortened as to prevent the recognition of a red light at a distance of two miles; and (*c*) those with a central scotoma for red and green. These dangerously color blind may be satisfactorily and expeditiously discovered with the Edridge-Green lantern after gaining an understanding of the principles of the test employed. The Jennings test, on the other hand, results in the rejection of a large percentage of subjects who should be accepted, especially among the more intelligent, but it possesses certain practical features which render it superior to other tests in certain lines of examination where great accuracy and classification of color defects are not essential. It should not be used for testing sailors and trainmen.

Among the 1,000 individuals tested, Collins finds about 8.6 per cent. of men and 2.2 per cent. of women color blind, though the defect is of a degree which would be dangerous in occupations requiring recognition of colored lights in only about 3.1 per cent. of men and 0.7 per cent. of women. Color blindness occurs less frequently in eyes apparently without demonstrable refractive error; it occurs most frequently in eyes showing mixed astigmatism.

Barrett (1) reports as a result of experiments upon himself and extensive tests on others, that form vision below 6/12 is dangerous in dull light and because it makes small colored spots unrecognizable. Köllner (8) claims that errors of refraction up to 20D have no effect on color mixture, though brightness is less well judged as the defect becomes more grave.

Bell (2) describes a spectral apparatus by means of which he attempts to classify color defects into 26 different types. His chief test is in principle the converse of Rayleigh's and consists in matching a synthetic yellow and a synthetic blue-green, of the same hues as the spectral colors corresponding to the red-yellow and blue-green junctions for the normal eyes, by shifting a pure spectrum which occupies the lower half of a slit in the focal plane of the eyepiece while the synthetic color occupies the upper half. The synthetic yellow is produced by the use of a filter made of opposed wedges of cobalt and selenium glass. The patient is asked to match the synthetic yellow by rotating a prism mounted on a turn table.

A very slight degree of red blindness causes him to match the synthetic yellow with a green, while a plus red or a minus green color-abnormality will produce a reddish match. Next the experimenter substitutes the synthetic blue-green filter, produced by cobalt chloride in acetone solution combined with a uranine filter, and the test is repeated. Here a green-blind observer would match with blue and a blue-blind case with green. This blue-green junction supplements the other in the diagnosis. Finally, for further evidence of plus or minus red or blue sensation, the red and violet end points are determined, after resting the eye. Of the 26 possible abnormal types of congenital color vision, the author claims to have found 16 fairly represented in his own work or in the cases reported by Burch, Abney, Watson and Edridge-Green. Seven of the remaining ten are types having two sensations plus and thus varying from a simple deficit of the remaining sensation only in the degree of luminosity of the other two. The best method of differentiation here seems to be by a careful study of the end points and the use of fatigue tests such as Burch describes.

As a remedial measure, Bell suggests the use of colored lenses to regain the proper balance of colors, as has already been done in artificial illumination to secure daylight values. An ordinary gas flame, for example, is in effect partially blue-blind and the normal eye will see colored objects under such a light very much as the partially blue blind would see them in daylight. The necessary correction has been found to be the interposition of absorbing media which reduce the green and red elements in the same degree as the deficit of the blue element in the source. The penalty of doing this is the loss of considerable luminosity. Those in whom one sensation is nearly or quite absent are of course quite beyond help, since balance would require an almost complete obscuration of the remaining sensations.

Nature (10) reports an interesting newspaper case of a soldier who saw everything green for some time after being shot in the forehead, the bullet passing out of the back of the head without killing or even stunning him and Hilbert (6) briefly describes a case of red vision after poisoning, a girl of eight years who ate some of the berries of the nightshade and reported that everything she looked at was as red as the berries she ate; Johnson (7) describes an interesting case of unilateral acquired total color blindness following a form of creeping paralysis which gradually affected the limbs of that side; Meyer (9) reports a case in which blue and green

are seen as one color, red and yellow another, thus having the neutral zone displaced into the yellow-green region; Williams (12) reports the results of extensive experiments upon a puzzling case which the author does not attempt to classify, preliminary tests with colored wools, papers, cards and glasses in the Iowa Psychological Laboratory being supplemented by careful spectral measurements in the Nela Research Laboratory; Von Kries (11) describes the results of the use of a number of familiar tests and some adaptations of old ones upon a subject whom he classifies as a deuteranomalous trichromate, the especial interest in the case arising from the fact that the defect is limited to one eye and may thus be expected to add to our information as to just how colors appear to subjects of this class.

Ferree and Rand (4) report the discovery of areas blind to different colors in the peripheral retinas of normal subjects, giving maps of these areas for two observers. These peripheral retina spots, while similar in a general way to the case described by Schumann, present the following points of difference. (*a*) There is no detectable weakening of the sensitivity to the complementary or antagonistic color in the areas in question. And (*b*) no more of the color to which the area was blind was required to combine to produce grey with the antagonistic or complementary color than was needed on the normal areas of the retina immediately adjacent. As these blind areas are not deficient in the after-image and complementary or cancelling reactions the authors suggest the possibility of explanation by appeal to the conception of different functional levels in the cerebro-retinal structure.

Goldschmidt (5) reports the results of a successful attempt to increase by systematic exercise the color discrimination of a subject classed as an anomalous trichromate. The author first attempted to give his subject confidence by assigning simple tasks with colored wools, and correcting and explaining mistakes: acquaintance with color names was developed by daily practice with pictures and colored objects; actual color discrimination was increased by the use of spectacles of different colors which were worn daily, two hours at a time. Tables of results of tests at different periods in the treatment are printed which seem to show decided improvement in color discrimination. The author especially recommends the treatment with colored glasses.

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HEARING

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Rich's experimental study of tonal attributes (9) was made with tones of three regions of vibrational frequency, 275, 550, and 1,100. The sounds were obtained from three Stern variators and communicated to the observer through interference tubes appropriately adjusted to eliminate all higher partials. The method of the experiment was one of paired comparisons, the observer being instructed to judge differences in two successive sounds (varying in vibrational frequency) with respect to the attribute under consideration. Vocality is not accorded a place among the attributes since no sharp turning point was found in the three regions appropriate to the vowels *u*, *o* and *a* respectively. "The judgments of vowel-quality seem rather to be judgments of perceptions, perceptions which we found ready-made in some observers, and built up in others. A long series of studies in the theory of vowels has shown

that a given vowel-sound always contains a predominating tone or tones in a certain region of the scale, and that the regions are approximately an octave apart. These predominating tones form the core of the perception of vowels. If, as in our experiment, the core is presented to an observer who is instructed to hear the vowel, the remaining elements are supplied in some individual fashion, and the vocal judgment is rendered."

Pitch appeared to be clearly attributive, though the limens varied among the seven observers. It was uniformly higher at 1,100 than at 275 and 550 vibrations. Disregarding the results of two exceptional cases, the limen varied from about one third to one vibration at the two slower frequencies. In respect to volume the author's earlier results are substantiated, which indicated that judgments of volume are made upon an attributive basis, and that the volume-limen tends to follow Weber's law. In this connection it is pointed out that Watt's assumption that the volume of a tone decreases by halves as the tone becomes an octave higher is not in accordance with these results which tend rather to show that volume-differences remain approximately constant for the same interval at any point of the scale.

Judgments of brightness appear to be attributive but the results point to the conclusion that this is an aspect of pitch; with respect to nomenclature "pitch-brightness" is suggested. The results on tonality were few but suggest the possibility of such an attribute and it is accorded tentative acceptance.

Ogden (7) advocates the acceptance of five attributes of sound: pitch, volume, intensity, duration and, in a tentative way, brightness; while tonality, vocality, and noisiness are explained as perceptual phenomena.

Schole (10) records the results of a variety of ingenious experiments upon vocality which support the Helmholtzian theory that vocalic sounds are due to partial vibrations rather than to a certain resonance of the buccal cavity, as advocated by Hermann (the formant theory). The regions of sound which characterize the vowels *u*, *o* and *a* were found to be those established by Köhler, but Schole regards the octave-intervals between vowels as fortuitous in high German vocalization. He differentiates three *a* sounds—grave, medium, and acute, as distinct features of definite non-overlapping regions of pitch. While Schole attributes vocality to the pure tones of these different regions of pitch, he regards the vowel-sound as a perceptual combination of harmonic partials.

His results are especially interesting in their demonstrations of the necessary presence of the characteristic pitch of a vowel when it is sung at different levels of the scale. The vowel-tone is for the most part intensified by resonance of the mouth cavity which changes its pitch as the tone is altered; when, however, the vowel is of a lower pitch than that of the mouth resonance, the latter is neglected and adjacent partials are damped to approximate the pitch which the particular vowel requires.

Abraham (1) determined the pitch of the mouth-tones or resonance when the different vowels were uttered, and found an ascending series comparable to that of Köhler, though the *u* tone was higher and the *i* tone lower, as Miller found them to be (cf. the BULL., 1917, 14, 186-7). These tones were fairly constant for men, women, and children. Brightness was found to vary with vocality, but the pitch of the mouth-resonance appeared to be less significant; overtones that correspond with the resonance of the mouth were intensified and thus rendered more noticeable, but they were more tonal than vocalic—the vowel being less clear at the points of resonance than elsewhere.

With a specially constructed apparatus which produces high tones of great purity and a variable intensity, Gildemeister (3) explored the upper region of hearing in fifty-one persons varying in age from 6 to 47 years. The tones were conducted by means of a telephone, both through the ear-passages and through the skull. With air-conduction and a fairly constant intensity, the limit of hearing was attained at about 20,000 vibrations for children; at the end of the adolescent period the limit had been lowered by about 1,000 vibrations; in the middle thirties it had decreased to about 15,000 vibrations, and it continued slowly to decrease until at age 47 it was fixed at about 13,000 vibrations. With bone-conduction the limit was a few hundred vibrations lower than with air-conduction. Increase of intensity increased the height at which tones could still be heard; but only by an interval of about a semitone, or some 1,100 vibrations, after the intensity had been increased 25 times. In a second paper Gildemeister (2) considers Wien's paradox that the amplitude of the higher resonating partials in a clang is not reduced sufficiently to cause them to become subliminal even when the fundamental has ceased to be heard, although in reality they are not heard under such conditions. The question is raised whether the limit of hearing is sudden and decisive or whether it is indefinite, and attributable to the increasing difficulty of arousing the higher

receptors. It has been suggested that a section of the basilar membrane must be agitated to produce the fundamental and when the intensity of stimulation is insufficient no sound is heard. If there be a definite limit to sound-perception this would mean that when a certain region is approached the possibilities of its resonance are insufficient to produce a tone, but if there is no such definite limit we ought to hear the corresponding high sounds when the intensity is sufficient for their production. It is also suggested that in regions of high pitch the hair-cells vibrate with the same amplitude and phase as does the *tectorius*; consequently no contacts are made to produce a sound, however intensive the agitation may be.

A new and promising theory of the mechanism of the inner ear is advanced by Wrightson (**14**), and supported by the detailed anatomical studies of Keith. This work is treated in a special review (cf. the BULL., 15, 445). Keith's anatomical discovery that the hairs from the nerve-cells of the organ of Corti are embedded in the tissue of the tectorius is substantiated by the independent discoveries of Wittmaack (**13**) who shows that faulty preparation of the organs has led to the false notion that the tectorial membrane is free. Wittmaack also questions the notion that the auditory nerve-terminals may properly be called "hair-cells," and speaks rather of a continuity of the organ of Corti and the tectorius—with nerve-fibers passing from the former into the latter structure.

Parker (**8**) gives a critical review of the investigations upon the sense of hearing in fishes; the results favoring the idea that fishes hear in varying degrees, some only loud noises, others apprehending sounds more in the nature of tones. Fishes lack the cochlear organ and experiments after nerve-sectioning and extirpation indicate that their organ of sound is the sacculus, since removal or destruction of the utriculus or the canals occasions interference with equilibrium, but not with response to sound.

Young (**15**) describes the construction of a tunable metallic bar which has certain advantages over the ordinary tuning-fork in experimentation on sounds. The bar is supported on stretched strings at its two nodes and the sound is heard with the aid of a stethoscope. The tone may be varied by a single load at one end, which can be calibrated with respect to adjustments of load, or the load can be varied in amount; in either case the resultant variations of pitch may be used in testing differential sensitivity. The sound of the vibrating bar is said to be free of variation in timbre

and intensity; it gives a loud, distinct tone which outlasts the resonated tone of a fork. Though the middle and the ends of the bar are in opposite phase (180 degrees), there is no interaural interference when one ear hears the vibration of the end, and the other ear that of the center. Differences of intensity can be secured by varying the position of the stethoscope from the node to the center, or to an end. Alteration of apparent localization of the sound follows a shifting of the tubes, starting with one at the end of the bar, which gives full intensity in one ear, and the other at the node, which gives no sound in the other ear. Keeping the distance constant, a shift in position varies the intensity in the two ears and tends to localize the sound in the direction of the ear which hears it most loudly. Stewart and Hovda (12) find that the ratios of intensities of a pure tone when conducted separately to the two ears must vary as much as one to ten in order to produce an apparent displacement of 45 degrees in localization. So great a difference never occurs in ordinary binaural experience, indicating to the authors that the intensity-factor alone is relatively unimportant, whereas they regard a difference of phase as the most significant factor. The angular displacement (θ) can be expressed in terms of right-ear and left-ear intensities (I_r and I_l) by the equation $\theta = K \log (I_r/I_l)$ with K a constant. This reminds one of Weber's law, but with an interesting difference inasmuch as the response indicated by the constructive angular displacement is proportional to the logarithm of the *ratio* of the two stimuli.

Klemm (4) has made an analytic study of the factors entering into the binaural localization of sound with the aid of a device which collects the sound-waves of a single source in two microphones, separated by the normal distance of the two ears, and conducts them separately to the two ears of the observer who is placed in another room. He finds that the intensity of the tone as heard in both ears is about four times that of the intensity for one ear alone. The two ears hear the same tone with somewhat varying intensity as well as with a variable pitch; as a rule the ears being one or two vibrations apart. The exactness of localization is found to be greater than would be warranted by a simple difference of intensity and it is finer when the ear is directly exposed to the sound than when the sound is conducted separately to the two ears through the microphones; although discrimination of intensity was not found to be affected by the different modes of conduction. Experiments were made in which the sound at the right was conducted

to the left ear, and *vice versa.* With the sounding bodies in view of the observer, a correction could be made so as to judge the source properly, but the observer did not become adapted to this shift, as Stratton did in his experiments with an inverted field of vision, for as soon as the normal connections were restored the observer made normal judgments. When the sound reaches one ear by 5 to 10 sigma in advance of the other, it is localized in the ear that hears it first. By direct hearing the observer could tell the difference in a sound located at 50 cm. distance, from one at 100 cm. distance, although the intensities of both had been made equal; this again indicates that a single source of sound is differently, and in some way more finely, apprehended than when the sound is separately conducted to the two ears.

Lantier (5) offers a report which places a high value upon the methods of Marage in diagnosing and treating cases of deafness incident to the war. From a study of cases in the field Lantier finds the method of measuring auditory acuity, previously referred to in these summaries (cf. the BULL., 1918, **15**, 83) to be fully reliable in differentiating actual and simulated cases of deafness; he likewise testifies to the value of auditory reëducation conducted by means of the *vowel-siren.* Marage (6) answers the criticism that war deafness in time will cure itself by referring to the absurdity of such a notion in the 75 per cent. of patients whose disturbance is attributable to lesions of the middle and inner ear. Among the remaining 25 per cent. of functional disturbances, some make rapid recovery under treatment while the hearing of others is permanently impaired.

Sizes (11) maintains that the Hindoo scale of 22 intervals is not an equal-interval scale, but the chromatic scale of Pythagoras; and that Arabian music, with its 18 intervals, is not a third-tone scale, but the same as the Hindoo scale after four flatted notes have been omitted.

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SYNESTHESIA

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Alford (1), after briefly reviewing some of the previous work upon synesthesia, describes an experiment he performed upon male twins, twenty-seven years of age, who associated colors with the names of persons and, as became evident during the course of the experiment, also with letters, numbers, days, months, and with a few of the cities. The twins were very much alike mentally. They also had the same likes and dislikes and had had a similar education, so that they seemed to the author to offer an excellent opportunity of discovering whether the phenomenon is due to some peculiar mental characteristics, to suggestion or to some merely accidental cause. Both of the men had a very good college record and were above the average in memory ability.

A list of 150 names, chiefly Christian names, was read to each and they noted the colors which were aroused. The color seemed as distinct to them as if it was "a colored object" and was not projected, but "seen in the mind." The reason for association could be discovered in the case of only a few of the colors such as Sue, blue; Flora, red, etc.

Of the 80 words which produced satisfactory responses there was an approximate agreement between the twins in the case of 54. One subject was tested again after three months and he made only two distinctly different reactions. In the second trial, however, he failed to respond to 19 words as against 7 words in the first trial. The author concludes that although there was 70 per cent. agreement, this agreement should have been much higher considering the small number of colors used in the associations and the numerous opportunities the twins had for similar experiences, and that, therefore, neither suggestion nor similarity of mental make-up can be considered the cause of synesthesia. He adds that if a more exact determination of the quality of the associations had been made there would have been even less agreement.

Peabody (2) sent a questionnaire to the members of the American Anthropological Association and of the American Folk-Lore Society and to several institutions, asking the following questions: (1) Whether in thinking of the numbers from 1 to 50 they arranged them in any definite shape or in a straight line; (2) whether they thought of the hours, days and months in a straight line, curve, circle or any other form; (3) whether they arranged the letters of the alphabet in their mind in any form. They were requested to illustrate if possible the arrangement they were accustomed to make. He received a hundred and sixty answers which he could use.

As was to be expected numbers and letters were most frequently arranged in straight lines either horizontally from left to right or perpendicularily from top to bottom of the page. It was not so clear to the author why the days were arranged more frequently in lines than the months.

48 per cent. of the subjects arranged the hours in a circle, clockwise, which left 52 per cent. who "resisted or escaped such an obvious stimulus to the imagination." Approximately 32 per cent. of the months, 21 per cent. of the numbers, 20 per cent. of the days, 13 per cent. of the letters, and 11 per cent. of the hours were arranged in some form or shape other than straight or broken lines. This ranking is in agreement with the results obtained both by Calkins and by Phillips. In the tabulation according to the more striking visualizations the months ranked first, followed by the hours, days, numbers and letters. Of the 160 answers 46 per cent. contained some sort of form. As many did not send in answers the author, on the basis of the results obtained, calculates that about 25 per cent. of all individuals possess some form of visualization of

one or more of the ideas investigated, although this may be somewhat too high. Many who had no form under one title possessed several under another. A number of illustrations of the forms reported are presented in the article.

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